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An Evaluation of MTO Specifications for Tree Planting and Maintenance

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An Evaluation of MTO Specifications for Tree Planting and Maintenance

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Abstract:	A four year study was undertaken to substantiate or refute Ministry of Transportation planting specifications. The study used green ash (**Fraxinus pennsylvanica**) trees planted in a clay soil to determine the effects of four planting techniques: 1) backfill/soil amendments, 2) top pruning, 3) surface treatment/weed control and 4) staking. A number of plant and soil parameters were measured during four growing seasons. At the end of four years the tree canopies were removed for detailed measurements and root systems in the backfill and surface treatments were dug and analysed. Based on the combined information from four growing seasons results indicated that amended soil, a surface treatment of woodchips or herbicide and a stake were most beneficial for tree growth and establishment. Pruning at planting provided only a limited benefit.
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An Evaluation of MTO Specifications for Tree Planting and Maintenance

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Executive Summary

There are conflicting reports in the literature and some differences of opinion among landscape professionals regarding the best methods of transplanting trees. Traditionally, planting specifications have mandated practices such as soil backfill amended with organic matter, pruning the tree to compensate for root loss during digging, mulching the planting area and rigidly staking the tree.

The purpose of this study was to evaluate four planting practices that were a part of the planting and maintenance specifications of the Ministry of Transportation.

A four year study (1985-1988) was undertaken to determine the effects of four planting techniques: backfill soil amendments, top pruning, surface treatment/weed control and staking. The study site was on the west side of Highway 86 south of Regional Road 17 near St. Jacobs. Soil at the site consisted of 7 to 10 cm of top soil overlying "heavy" grey clay. Three metre tall green ash trees were planted in augured holes that were 60 cm wide and 30 cm deep. Parameters such as shoot growth, trunk taper or diameter, leaf water potential, canopy density, leaf colour, leaf scorch, foliar nutrient content, soil moisture and soil temperature were measured in most or all years. At the end of the study roots of the backfill and surface treatment trees were excavated for observation and measurement. Results in this report concentrate on the final year of study (1988). Reports from previous years have been published.

A summary of the results reveal:

Backfill soil amendments
- Amended soil resulted in increased shoot length and dry weight, greater canopy density and more fibrous root growth.
- Amended and half amended soil resulted in greater trunk growth.

Surface treatment/weed control
- Woodchips or herbicide resulted in increased shoot length and dry weight, greater canopy density, less leaf scorch and more intermediate size roots.
- Herbicide resulted in the most dark green leaf colour.
- Woodchips resulted in more small and large roots.

Pruning
- Removing one third of all lateral branches resulted in increased shoot growth and reduced trunk taper in the first year. The effect diminished by the second year.

Staking
- Unstaked trees had greater lean than staked trees.
- Among staked trees lean was visually less with short stakes remaining three years but statistically lean was not different among the four staking treatments.
- Tall (150 cm) stakes resulted in more negative trunk taper (adverse effect) and the potential for less stable trunks in the first year.

Based on the results of this study trees should be planted in amended soil, the soil surface should be mulched or a herbicide used to control weeds and short stakes should be used for three years. Pruning one third off all lateral branches is of little or no benefit.

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1/ Introduction

Trees are very desirable components of the roadside environment. They help to reduce wind thus reducing soil erosion, snow drifting and aerial drift of deicing salt. Trees enhance road safety by providing sight delineation and directional clarity and by reducing driver fatigue through aesthetic visual enhancement. Roadside trees also lower maintenance costs and enhance adjacent property values. In excess of $1MM are spent annually by the Ministry of Transportation (MTO) to establish new plantings of trees along Ontario's roadsides.

While trees and shrubs are naturally slow growing during the first one or two years after transplanting, many roadside plantings have exhibited reduced growth long after the initial establishment period.

There has been much debate within the landscape industry as to the best method of transplanting woody plants. Traditionally, planting specifications have called for a high percentage of organic material in the backfill, and often the backfill material is composed entirely of material foreign to the planting site. In addition, quantities of fertilizer are often added to the backfill. Most specifications call for pruning the tree at planting (to compensate for root loss during digging), mulching the planting area, and rigidly staking the tree.

Published research results questioning the validity of amended planting soils have fuelled the debate over this traditional horticultural practice. Numerous studies have revealed no growth differences between trees planted in amended or unamended soils (Corley, 1984a; Corley, 1984b; Feucht, 1979; Schulte and Whitcomb, 1975; Whitcomb et al, 1976). In some cases, the use of soil amendments was found to be detrimental to tree growth after transplanting (Schulte and Whitcomb, 1975; Townsend, 1973; Wagar, 1982; Whitcomb, 1979).

In contrast to these results, there have been positive plant responses to soil amendments. Amending the backfill soil with sand reduced both the shoot:root ratio and xylem water potential in holly (Randolph and Wiest, 1981). A thorough study of various amendments on both clay loam and loamy coarse sand soils found that replacement of the site soil with a loam soil maximized growth after transplanting (Pellet, 1971). Roots have been observed to proliferate in amended soils as a result of the optimal conditions present for growth (Barnett et al, 1983; Feucht, 1979; Schulte and Whitcomb, 1975; Whitcomb, 1979). In the long term however, root growth may be confined to the planting hole and, as the canopy of the tree increases in size, the ability of the confined root system to provide support and supply the canopy with water and nutrients will decline (Whitcomb, 1979).

Conflicting results have been reported as to the effect of pruning on survival and growth after transplanting. Most results indicate that pruning stimulates shoot elongation and tree vigour (Castle, 1983; Oskamp, 1930). However, where root response was also measured, the stimulation of shoot growth by pruning was accompanied by an inhibition of root growth (Fordham, 1972: Head, 1967; Kandiah et al, 1984; Kelly and Moser, 1983; Knight, 1934; Randolph and Wiest, 1981; Wrigley and Smith, 1978; Young and Werner, 1982; Young and Werner, 1984). Traditional transplanting practices dictate that trees should be pruned at transplanting to "balance" the top and root or to reduce the quantity of top

growth that must be supported by a reduced root system (Anon., 1963; Anon., 1977; Flemer, 1982; Himelick, 1981; Thompson, 1954). The actual experimental results previously cited indicate that pruning may actually inhibit tree establishment by stimulating shoot growth at the expense of root growth.

A layer of mulch material is commonly placed on the soil surface around transplanted trees. This practice is supported by extensive research that shows clearly the benefits of mulching (Fraedrich and Ham, 1982; Litzow and Pellett, 1983; Whitcomb, 1979; Whitcomb, 1980; White and Holloway, 1967). Mulched trees had a higher rate of survival and greater height, shoot, and diameter growth (Buller and Gibbs, 1952; Fraedrich and Ham, 1982; Litzow and Pellett, 1983; Whitcomb, 1979). The use of mulches also increases the quantity of root growth (Coker, 1958; Fraedrich and Ham, 1982; Whitcomb, 1980; White and Holloway, 1967). Root growth under mulches often occurs at the soil/mulch interface or directly into the mulch material (Coker, 1958; Fraedrich and Ham, 1982). This would be detrimental if the mulch were removed at a later date or if the temperature or moisture conditions within the mulch were subject to extreme variations.

Mulching reduces soil moisture loss, moderates temperature fluctuations in the soil, reduces competition from weeds and, in the case of organic mulches, can contribute to the fertility and structure of the soil. Numerous mulching materials are used, the majority of which are organic (woodchips, straw, peat, corncobs, pine needles, compost, bark, grass clippings, leaves, and other organic refuse), although some inorganic materials are used (plastics, geotextile fabric, stone, and sand). Each material possesses different characteristics when used as a mulch.

As an alternative to mulch, herbicides have been used to prevent vegetation from competing with recently transplanted trees for water and nutrients (Atkinson, 1977; Barber, 1984; Nielson and Wakefield, 1978; Shipman, 1974; White and Holloway, 1967). Under a herbicide treatment, roots proliferate in the area where grass is removed by the herbicide, presumably in response to reduced competition (Atkinson, 1977). Herbicide treatments compared favourably with the use of organic mulches, although in some cases organic mulches were found to be superior. The main advantage of using herbicides over mulching is the lower cost of herbicide application.

Transplanted trees are traditionally staked rigidly to prevent wind knock-down, root damage from wind shifting, and to encourage straight trunk development. Early researchers discovered the importance of wind-induced tree motion in the development of a solid trunk (Jacobs, 1954). More recent research indicated that rigidly staked trees may develop less trunk taper and a reduced ability to remain upright after the stake was removed (Harris, 1984; Harris and Hamilton, 1969; Leiser et al, 1972; Wrigley and Smith, 1978). These studies cited have been performed with different species and under different environmental conditions than those commonly found in Ontario.

The University of Guelph was approached by MTO to design and execute a study of roadside planting and maintenance techniques that would be valid for the Ontario roadside environment. The objective of this study was to determine the validity of specific tree planting practices and procedures currently required by MTO specifications and after discussion with MTO staff to recommend alterations, if warranted, to the specifications based upon the results of the study.

2/ Materials and Methods

2.1/ Site Selection and Planting

In order to maximize the value of this study to the Ministry, it was decided that the major experiment would be carried out on a "typical" roadside site. Several possible sites were submitted by MTO staff.

A site was selected just south of Regional Road 17 on the west side of Highway 86 near the village of St. Jacobs (Fig. 1). The site was relatively flat, easily accessible, and had sufficient area to adequately house the experiment. Soil at the site consisted of 7 to 10 cm of top soil overlying "heavy" grey clay. Top soil at the site contained 37% sand, 47% silt, 16% clay and 4% organic matter. Clay sub soil contained 10% sand, 49% silt, 41% clay and 0.6% organic matter. Both types of soil had a pH of 7.1. The site had some very wet, poorly drained areas. These areas were easily distinguishable in early spring and the experimental plot was designed to exclude them.

The site was laid out and 60 cm dia. holes were augured 30 cm deep in late April 1985. The clay removed by the auger was used either in planting the unamended backfill trees or mixed with amended soil in planting the half amended soil in planting the half amended backfill trees (see section 2.2 for backfill soil amendments). The amended soil brought to the site contained 74% sand, 19% silt, 7% clay and 3.3% organic matter. Trees were planted with the assistance of the MTO Stratford District landscape crew during the first three days of May 1985. The amount of clay available from around the augured holes was insufficient to meet the needs of the unamended backfill treatment. To provide additional clay soil for planting clay was excavated from an area just south of the experimental site. All of the trees were watered by MTO with a water-fertilizer solution (6kg 20-20-20 per 1000 litres) immediately after planting. The trees were watered again August 8 and 9, 1985. Watering requirements were low due to the high rates of precipitation during the first growing season.

The staking treatments were applied shortly after all of the trees were planted (Fig. 2). Ash trees were pruned during late May 1985. A hardwood chip mulch (Fig. 2) was applied to one-third of the trees on June 10. The herbicide Round Up (1% solution) was applied each year as required (normally once in late May and again in late summer) to keep the one treatment weed free.

2.2/ Experimental Design and Treatments

Green ash (Fraxinus pennsylvanica) was used for the study. Trees were selected in the field from the Ministry of Natural Resources nursery at Midhurst. The trees were multi-branched, approximately 3 m tall and had an average trunk diameter of 24 mm. Prior to planting trees were stored at and shipped from the MTO Stratford district yard.

Colorado spruce was also selected for the study and planted. However, as a result of transport damage and poor survival the spruce study was abandoned.

The specific treatments were:

1) Backfill/Soil Amendment
   a) unamended -- clay soil from the site
   b) half amended -- equal parts by volume of unamended and amended
   c) amended -- as per MTO specifications
2) Pruning
   a) none
   b) one-third of all lateral growth was removed -- as per MTO specifications
3) Surface Treatment
   a) 10 cm of woodchips -- as currently in MTO specifications
   b) herbicide to provide a weed-free ring (60 cm dia.)
   c) no surface treatment
4) Staking
   a) 75 cm height, 1-year duration
   b) 75 cm height, 3-year duration
   c) 150 cm height, 1-year duration
   d) 150 cm height, 3-year duration
   e) none

The experiment was a rectangular lattice design in a factorial arrangement with three replications (blocks) of the basic design. This design allowed each treatment effect to be isolated individually and also allowed pooling of results if a particular treatment or treatments prove to have no effect. The total number of ash trees was 270 with 90 trees per replicate (block). An individual tree in a block received one each of the amendment, pruning, surface and staking treatments (3x2x3x5=90).

Measurements in this report concentrate on those used in the final year of the study (1988). The trees were removed from the site in September 1988.

2.3/ Plant Measurements

2.3.1/ Shoot length -- In September 1988 tree canopies were removed in order to determine total shoot growth for the 1987 and 1988 growing season. Data were expressed as the sums of the shoot lengths per tree for each of the two seasons. By contrast, shoot growth data in 1985 and 1986 were the mean length of 10 current season shoots selected at random within the canopy.

2.3.2/ Shoot dry weight -- Shoot growth from the 1987 and 1988 seasons was dried to constant weight at 70°C and then weighed.

2.3.3/ Trunk taper -- Diameter was measured in the spring and fall of each year at 80 and 160 cm above the ground. These two heights were just above the two staking heights. Taper was calculated by the formula;

$$\text{Taper} = \frac{\text{Diameter (at 80 cm) - Diameter (at 160 cm) (mm)}}{\text{Height difference of measurements (80 mm)}} \times 1000$$

The change in taper was the difference between the taper in the spring and that in the fall.

2.3.4/ Leaf water potential -- Leaf water potential was measured once in June and once in July each year. Individual ash leaves were excised at base of the petiole with a razor blade then immediately sealed in the pressure chamber for determinations.

2.3.5/ Canopy density -- Density was assessed visually at the end of each growing season and rated as; 1 - sparse/open, 2 - intermediate, 3- full, moderately dense.

2.3.6/ Leaf colourations -- Colour was assessed visually during July 1987 and 1988 and rated as; 1- Pale greenish yellow, 2 - light green, 3 - dark green.

2.3.7/ Leaf scorch -- Scorch was assessed visually at end of July 1988 and rated as; 0 - no scorch, 1 - less than 25% scorch, 2 - 25-50% scorch (moderate), 3 - more than 50% scorch (severe).

2.3.8/ Lean -- Trees were assessed visually and rated as; 0 - no lean (0 to 10 degrees off vertical), 1 - leaning (more than 10 degrees off vertical).

2.3.9/ Foliar nutrient content -- Twenty leaves were removed from the backfill and mulch treatments in mid August 1987 and 1988 and oven dried. Percentages of nitrogen, phosphorus, potassium, calcium and magnesium were determined.

2.3.10/ Root dry weight -- In early September 1988 Roundup herbicide (1% solution) was sprayed around the base of trees to minimize the amount of grass roots in the tree root zone. Trees with backfill and surface treatments were selected for digging. A 150 cm (60") tree spade was used to remove intact soil balls (Fig. 3). Soil was removed first with hand shovels followed by high pressure washing (Fig. 4). Tree roots were separated into three grades; small - less than 3 mm dia., medium - 3 to 10 mm dia. and large - 10 to 25 mm dia. Roots were oven dried to constant weight at 70°C then weighed.

2.4/ Soil Measurements

2.4.1/ Soil moisture -- Measurements were taken once in June and once in July 1986, 1987 and 1988 using a "quick draw" tensiometer which gives a measure of soil suction. A zero reading indicates that the soil is saturated.

2.4.2/ Soil temperature -- Temperature measurements were taken for nine consecutive weeks beginning in June 1988 at the soil or mulch surface and 15 cm below the surface for the backfill and surface treatments.

2.5/ Weather Data

Data from Environment Canada at Waterloo Wellington Airport were used to represent the precipitation at the experimental site (Fig. 5).

3/ Results and Discussion

Data in this report concentrate on the final year of the study (1988). However, results from previous years are cited in order to provide a more complete analysis of the study. Results concentrate on statistically significant effects thus parameters not discussed can be assumed to be non-significant.

3.1/ Shoot length

Shoot length was significantly greater in amended than in unamended soil in both 1987 and 1988 (Fig. 7). During earlier years shoot elongation followed a similar trend.

These results are in contrast to some studies that revealed no growth differences between amended and unamended soils (Corley, 1984a, 1984b; Feucht 1979). The beneficial effects of amended soil were probably due to increased growth in the one or two years after planting as a result of improved physical properties of the soil. These results are substantiated by root growth data. During root excavation in 1988 it was noted that roots of all three backfill treatments had penetrated both the top soil and clay beyond the augured hole. Thus roots were not confined to the hole or to the area of amended soil within the hole as has been suggested may occur (Whitcomb, 1979).

Among the three surface treatments shoot length was similar for trees with woodchip mulch or herbicide and was significantly greater than that for untreated trees during 1987 and 1988 (Fig. 6). In 1986 shoot elongation was significantly greater for trees with woodchips than for those with herbicide or untreated trees. The beneficial effects of a surface treatment such as woodchips or herbicide were probably due to reduced competition from weeds. Fraedrich et al (1982) reported better growth of mulched trees.

Pruning at planting time (1985) did not influence shoot length during 1987 or 1988. In 1985 pruned trees were significantly taller by the end of the growing season and in 1986 pruned trees had significantly greater shoot length. Pruning reduces the number of growing points and thus stimulates the growth of remaining shoots and the carbohydrate distribution to them.

Overall, staking had little if any effect on shoot length throughout the years of this study. Staking effects on other growth parameters are discussed in subsequent sections.

3.2/ Shoot dry weight

Trees in amended soil had significantly greater shoot dry weight in 1987 compared to those in half amended or unamended soils (Fig. 7). No significant differences were recorded in 1988 although there was a trend for greater shoot weight in amended and half amended soil compared to unamended soil.

Shoot weight of trees with woodchip mulch or herbicide was similar and significantly greater than for untreated trees in both 1987 and 1988 (Fig. 6). As would be expected shoot dry weight results were rather similar to those for shoot length.

3.3/ Change in taper and trunk diameter

Taper is an important factor that determines vigour and ability to hold the canopy effectively (Leiser and Kemper, 1973). Increasing values indicate greater trunk development, being greater at the base and tapering with height. In 1985 top pruning and staking at 150 cm resulted in significantly reduced taper, while soil amendments had no effect on taper development. These results were in agreement with Harris, 1984 and Leiser et al. 1972. In 1986 none of the pruning, staking or amendment treatments had a significant effect on taper. Taper could not be calculated accurately in 1987 or 1988 because of branching that occurred below the 160 cm measuring height.

Trunk growth was influenced by staking treatments in 1987. Trees staked for three years with tall stakes had significantly more trunk growth at 80 cm. than trees staked for one year with short stakes. However, trees with greater trunk growth at 80 cm may not necessarily have more positive taper. No significant differences were recorded in staking treatments in 1988. As tree root systems become larger the effect of staking would be expected to diminish.

Comparisons of trunk diameter growth at 80 cm in 1987 and 1988 revealed that trees with amended or half amended soil had more trunk growth than those in unamended soil in 1987. In 1988 a similar trend was observed however, the difference was not significant (Fig. 8). Perhaps, as the roots penetrate out from the amended region of the planting hole the effect due to amendments diminished.

Among the surface treatments trunk growth was significantly greatest for trees with woodchips, intermediate for those with herbicide and least for untreated trees in 1987 (Fig. 8). During 1988 trees with woodchips or herbicide were similar, with significantly greater trunk growth than for untreated trees. In the present study more small fibrous roots were recorded in trees treated with woodchips or herbicide. This result probably explains the additional trunk growth of treated trees, occurring because of increased water and nutrient absorption.

3.4/ Leaf water potential

No differences were recorded in leaf water potential during June or July 1988 as a result of amendment or surface treatments (data not shown). However, leaves appeared to be more wilted on unmulched trees. The least wilting appeared to be on trees with woodchip mulch. Mulching conserves moisture by retarding surface evaporation and eliminating competing weeds.

3.5/ Canopy density

Data recorded as a visual rating revealed that trees in amended soil had more significantly dense canopies than those in unamended soil (Fig. 9). Trees in half amended soil were not significantly different from the other two amendment treatments. Also, trees with a surface treatment of woodchips or herbicide had significantly more dense canopies than untreated trees in 1985, 1987 and 1988 but not in 1986 (data not shown).

3.6/ Leaf colour

Colour ratings recorded during 1987 and 1988 revealed that trees with the herbicide surface treatment had significantly more dark green leaves than trees

with woodchips or untreated trees (Fig. 10). Extensive weed growth probably competed with untreated trees for nutrients and water. Also, microbial decomposition of the woodchips may have utilized some nitrogen at the soil surface where extensive fine roots grew. However, there was no difference in leaf nitrogen level due to surface treatments (data not shown).

3.7/ Leaf scorch

Scorch was recorded only during 1987 and 1988 because of the extended dry periods. Trees with herbicide or woodchip mulch had significantly less scorch than untreated trees (Fig. 11). More scorch in untreated trees could have been due to higher surface temperature in conjunction with low moisture as a result of weed competition.

3.8/ Lean

At the completion of the study unstaked trees, as would be expected, leaned more than those that were staked. Lean resulted from wind movement in the first or possibly second growing season before root establishment. Data in 1988 revealed that lean appeared to be least for trees staked for three years although there was no significant difference in lean rating among the four staking treatments. (Fig. 12). This result indicates that, in the clay soil at the study site, roots apparently were less able to anchor the trees sufficiently after only one year. Trees growing in more optimum site conditions where roots could become established more quickly may be less subject to being moved by the wind after one year.

3.9/ Foliar nutrients

There were no differences during 1987 or 1988 in nitrogen, phosphorus, potassium calcium or magnesium content of leaves among any of the amendments or surface treatments (data not shown). The darker green leaves of herbicide treated trees was not due to leaf nutrient levels and remains unexplained.

3.10/ Soil moisture

Soil moisture, measured tensiometrically, was not different as a result of either backfill or surface treatments in 1988, although there was a trend for the least moisture stress with woodchip mulch (Fig. 13). This observation was supported by the finding that there was less leaf wilting and less leaf scorch in trees with woodchip mulch. In 1985, 1986 and 1987, abundant soil moisture throughout the growing season resulted in near field capacity condition.

3.11/ Soil temperature

Temperatures were very inconsistent during the nine consecutive weeks of measurement in 1988. Soil amendment treatment had no effect on temperatures at the soil surface or at the 15 cm depth on any of the dates (data not shown). Surface temperatures were lower under woodchips than those for the herbicide or untreated surface for five of the nine weeks (Fig. 14). This result would be expected because of the insulating effects of woodchips. At the 15 cm depth, temperatures were lower under woodchips and unmulched trees on only three of nine dates (Fig. 15). Similar inconsistencies in soil temperature were recorded in previous years.

3.12/ Root dry weight

Evaluation of tree roots excavated in 1988, after four years of growth, revealed

that trees with amended backfill had more small (fine) fibrous roots (< 3 mm dia.) than unamended trees (Fig. 16, 17). Increased fine root growth in amended soil was probably the result of better physical conditions of soil. Weight of small roots was higher for trees with woodchip mulch than for herbicide or untreated trees (Fig. 16, 18). More small roots under woodchip mulch may be the result of lower surface temperatures and more moisture at the soil surface under woodchips.

Trees with woodchips or herbicide treatments had greater weight of medium sized (3-10 mm dia.) roots than untreated trees (Fig. 16). There were no differences in weights of large (10-25 mm dia.) roots due to any of the amendment treatments, but woodchips produced more large roots than either herbicide or no surface treatment.

3.13/ General observations

Ash was selected for this study because of its ability to grow well in very moist soil. Had a species been planted that was less tolerant of moisture and low soil aeration the results may have differed from those reported here.

The clay soil at the site dried out very slowly yet water was able to move through. Limited trials with a permeameter that measured the rate of water movement in the soil indicated that movement was variable even within an area of only several square meters. This variability indicated erratic water movement through the clay probably as a result of minor fissures. The layer of loam soil prevented the clay from becoming excessively dry or from cracking extensively as it would have done at the soil surface.

Root excavation of the trees in the backfill soil amendment and surface treatments revealed that roots were within 75 cm of the trunk. There was no increased root density within the original planting hole thus root penetration into the clay soil did not appear to be restricted. Although root density was greater in the surface 30 cm, there was no increased root growth in the top soil above the clay.

The trees on the site were rarely under water stress. In the summers of 1985, 1986 and 1987 (except April and May) there was above normal rainfall. Had the trees been under water stress the woodchip mulch or herbicide treatment may have been beneficial.

	Shoot elongation		Total shoot length		Shoot dry weight		Height growth	Bud development	Trunk taper change			Trunk diameter increase		Leaf water potential				Canopy density				Leaf colour		Leaf scorch		Visual leaf wilt	Defoliation date		Lean		Foliar nutrients		Soil moisture			Soil temperature								Root dry weight		
	85	86	87	88	87	88	85	85	85	86	87	87	88	85	86	87	88	85	86	87	88	87	88	87	88	88	85	86	87	88	87	88	86	87	88	85 0	85 15	86 0	86 15	87 0	87 15	88 0	88 15	88 S	88 M	88 L
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A	0	0	+	+	+	+	++	+	0	0	0	+	+	-	0	0	0	+	0	+	+	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0		0		0		0		+	0	0
HA	+	0	0	0	0	0	+	+	0	0	0	+	0	-	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0		0		0		+	0	0
U	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0		0		0		0	0	0
Pruning																																													
P	0	+	0	0	0	0	+		-	0	0	0	0					0		0	0	0	0	0	0			0	0																
HP	0	0	0	0	0	0	0		0	0	0	0	0					0		0	0	0	0	0	0			0	0																
Surface																																													
W	0	+	+	+	+	+					+	++	+	0	0	0	0	+	0	++	+	0	0	-	-	-		0	0	0	0	0	0	0	0	0	+	-	+	0	0	+	+	+	
H	0	0	+	+	+	+					+	+	+	0	0	0	0	+	0	+	+	+	0	-	-	-		0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	
U	0	0	0	0	0	0					0	0	0	0	0	0	0	+	0	+	+	+	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Staking																																													
S1	0	0	0	0					0	0	0	-	0															-	-																
S3	0	0	0	0					0	0	0	0	0															-	-																
T3	0	0	0	0					-	0	0	0	0															-	-																
T3	0	0	0	0					-	0	0	+	0															0	0																
N	0	0	0	0					0	0	0	0	0																																

Amendment: A=amended, HA=half amended, U=unamended; Pruning: P=pruned, NP=not pruned; Surface treatment: W=woodchips, H=herbicide, U=untreated; Staking: S1=short stake for one year, S3=short stake for three years, T1=tall stake for one year, T3=tall stake for three years, N=not staked.

In each treatment (vertical) and measured parameter (horizontal) combination, within year, values are + (significantly greater), 0 (not significantly different) or - (significantly less) than the "control" treatment. Control treatments were amendment U, pruning NP, surface U and staking N. For example, half amended backfill increased shoot elongation compared to amended or unamended backfill in 1985.

Unlisted (blank) values indicate that no data were recorded. For example, staking would not be expected to affect leaf water potential or leaf colour.

Lower values for leaf water potential in 1985 in A and HA occurred in only one of the three blocks.

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Fig. 1. View of experimental site along Hwy 86, south of Regional Road 17.

Fig. 2. Green ash trees were staked at 150 cm (foreground), at 75 cm (background) or not staked. Surface treatments were wood-chips (foreground), herbicide or no treatment.

Fig. 3. Excavation of 150 cm (60") soil ball with a tree spade, September, 1988.

Fig. 4. High pressure washing effectively removed soil from the roots.

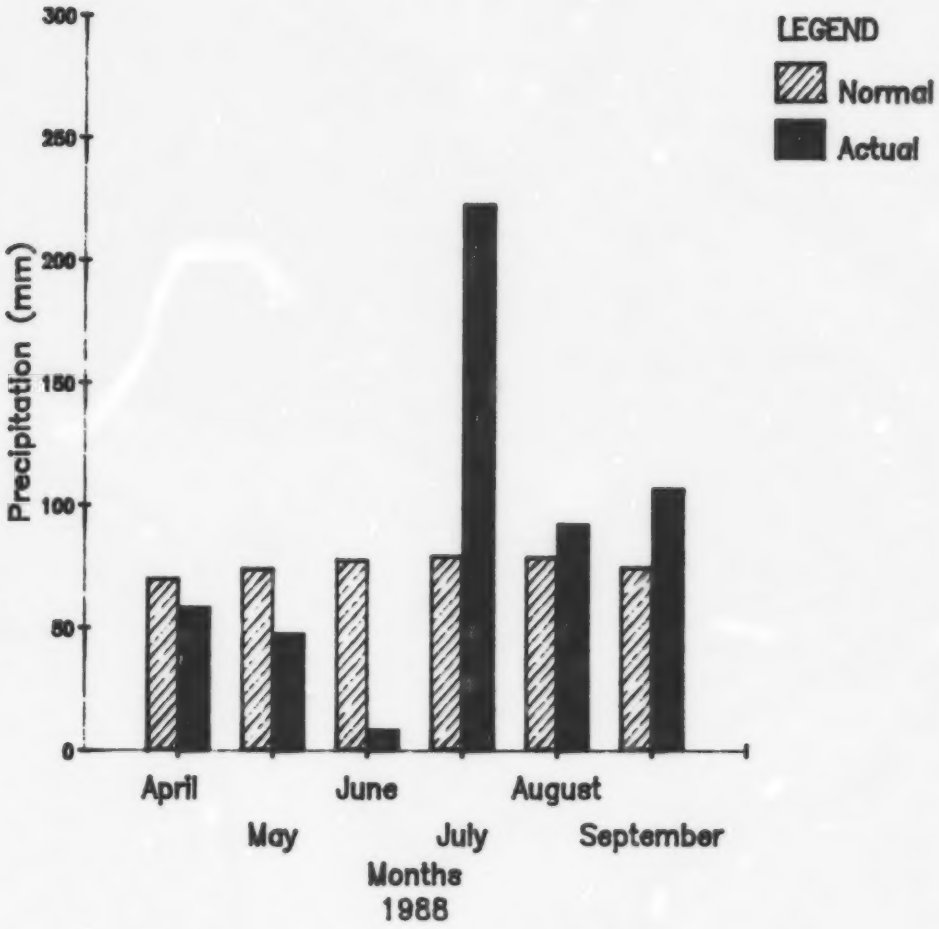
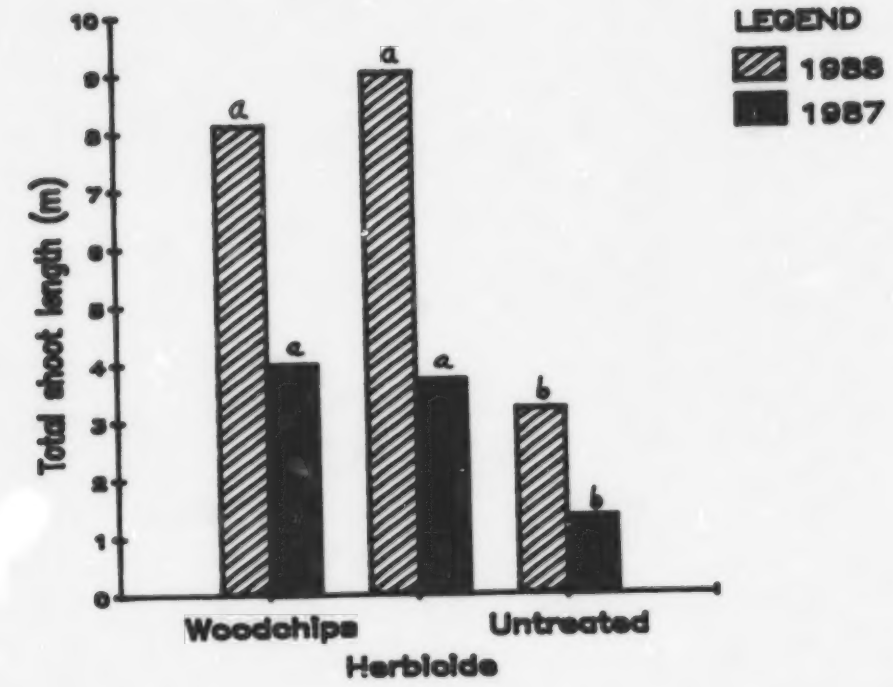


Fig. 5. Monthly precipitation summary for April to September 1988.



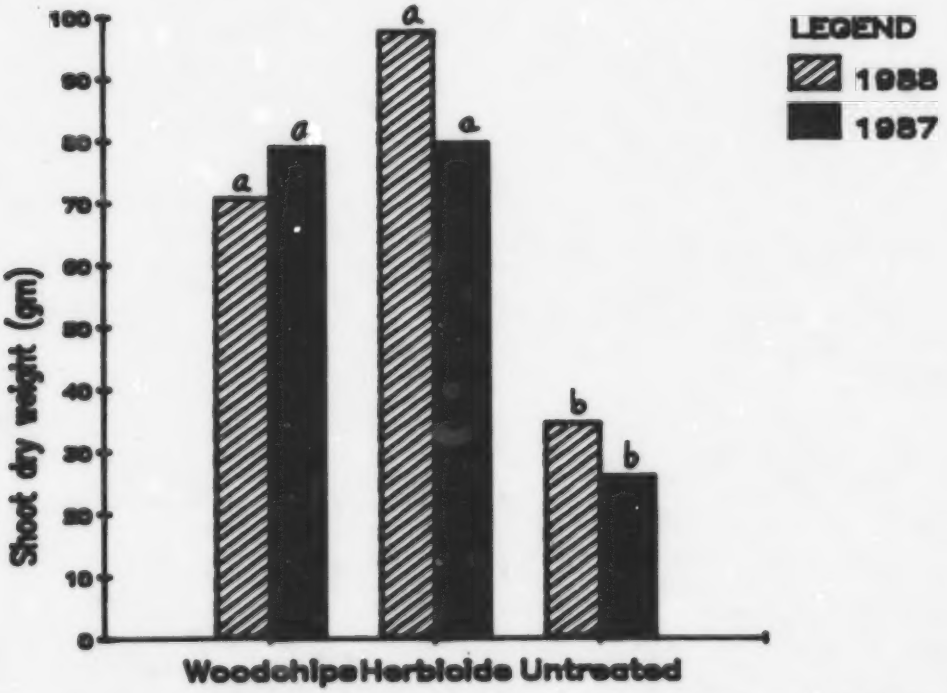


Fig. 6. Shoot length (above) and shoot dry weight (below) as influenced by surface treatments. Bars with similar letters, within years, are not significantly different (P = 5%, LSD).

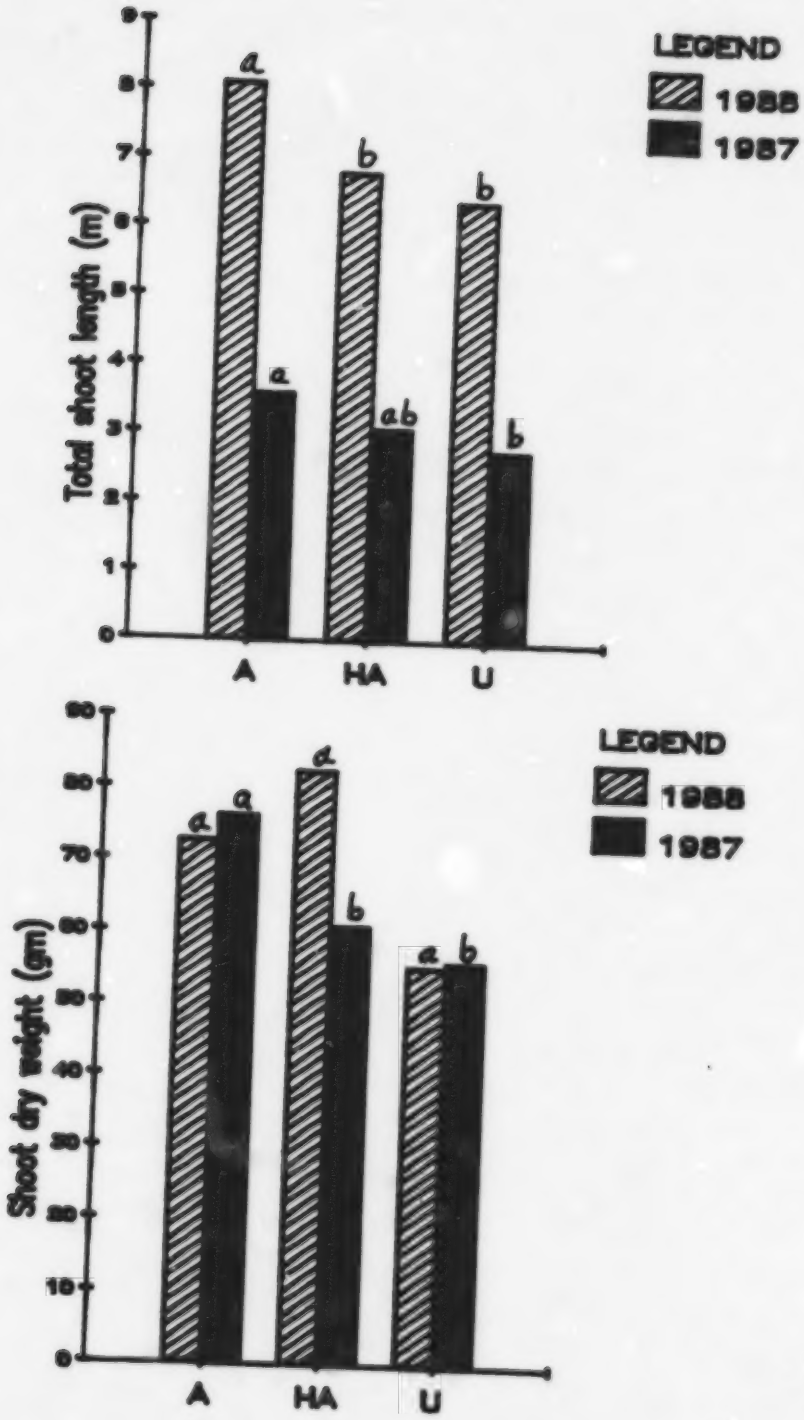


Fig. 7. Shoot length (above) and shoot dry weight (below) as influenced by soil amendments. A - amended, HA - half amended, U - unamended. Bars with similar letters, within years, are not significantly different (P - 5%, LSD).

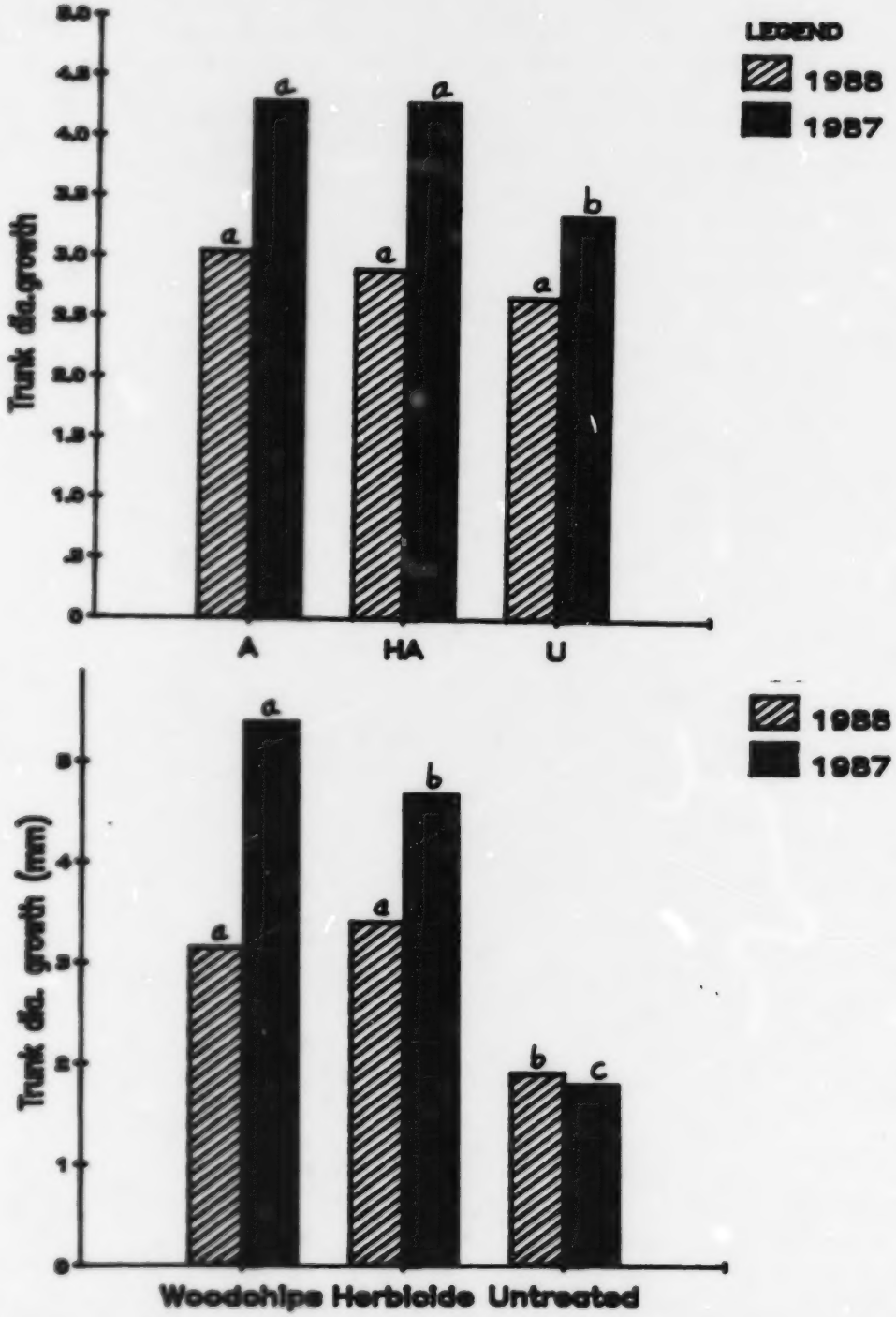


Fig. 8. Trunk diameter growth (measured at 80 cm) as influenced by soil amendments (above) and surface treatments (below). A = amended, HA = half amended, U = unamended. Bars with similar letters, within years, are not significantly different (P = 5%, LSD).

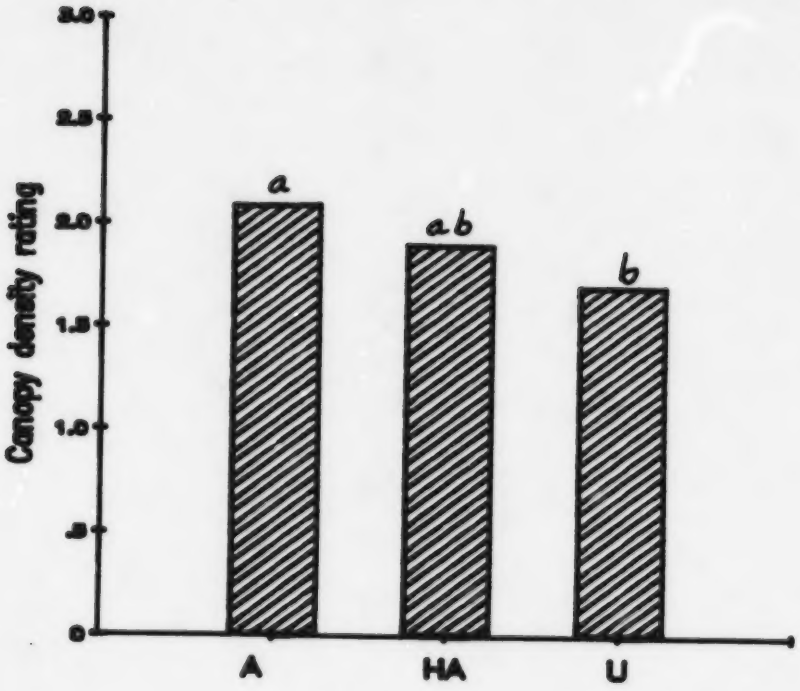


Fig. 9. Canopy density rating in 1988 as influenced by soil amendments. A - amended, HA - half amended, U - unamended. Ratings: 1 - sparse/open, 2 - intermediate, 3 - full, moderately dense. Bars with similar letters are not significantly different (P - 5%, LSD).

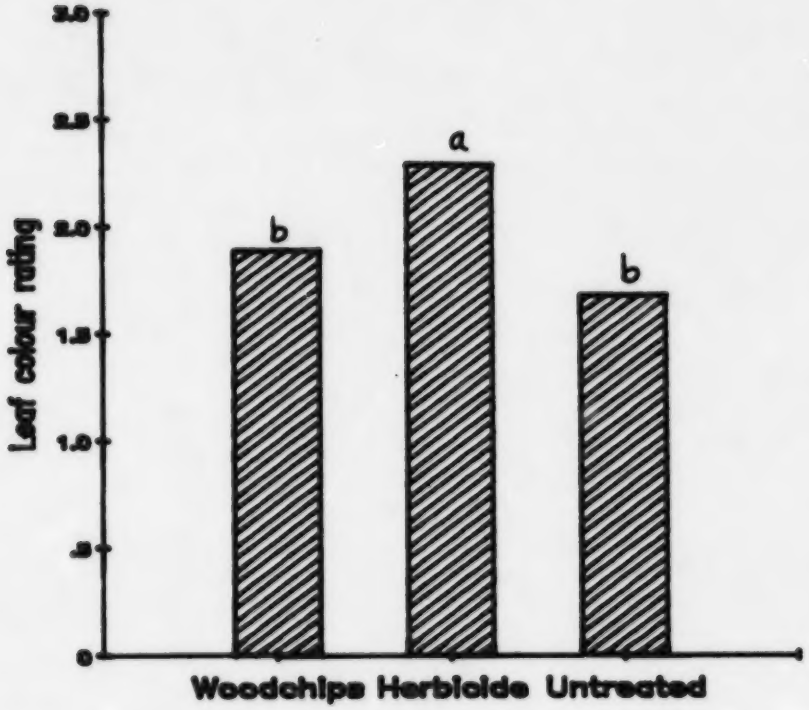


Fig. 10. Leaf colour rating in 1988 as influenced by surface treatments. Ratings: 1 = pale greenish yellow, 2 = light green, 3 = dark green. Bars with similar letters are not significantly different (P = 5%, LSD).

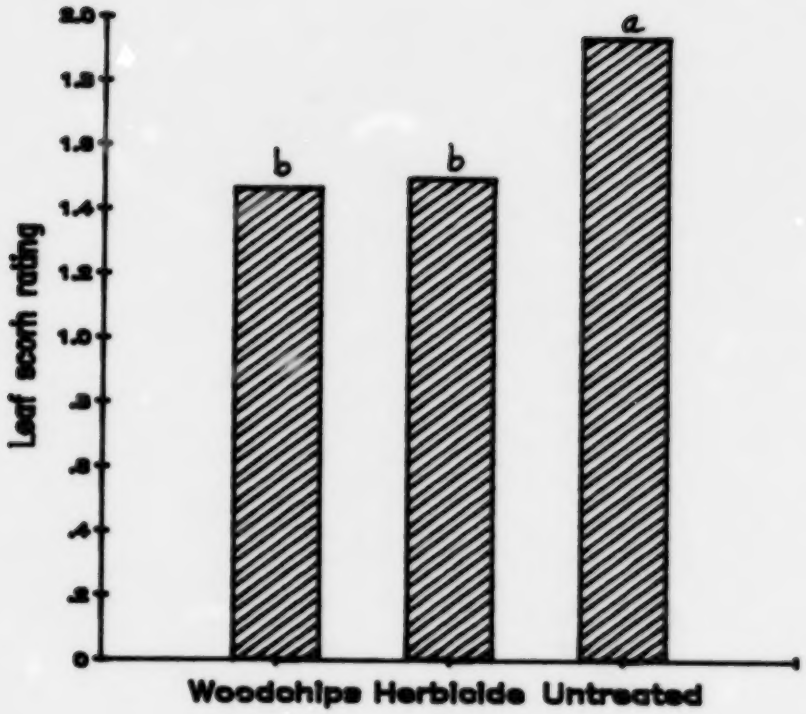


Fig. 11. Leaf scorch rating in 1988 as influenced by surface treatments. Ratings: 0 = no scorch, 1 = less than 25% scorch, 2 = 25 to 50% scorch, 3 = severe (50% or more) scorch. Bars with similar letters are not significantly different (P = 5%, LSD).

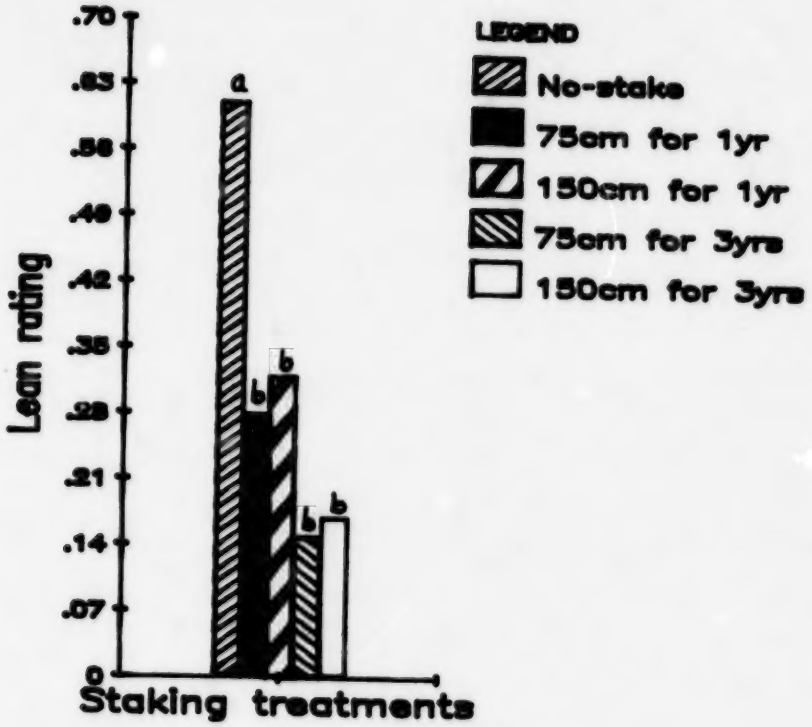


Fig. 12. Lean rating in 1988 as influenced by staking treatments. Rating: 0 = no lean (0 to 10 degrees off vertical), 1 = leaning (more than 10 degrees off vertical). Bars with similar letters are not significantly different (P = 5%, LSD).

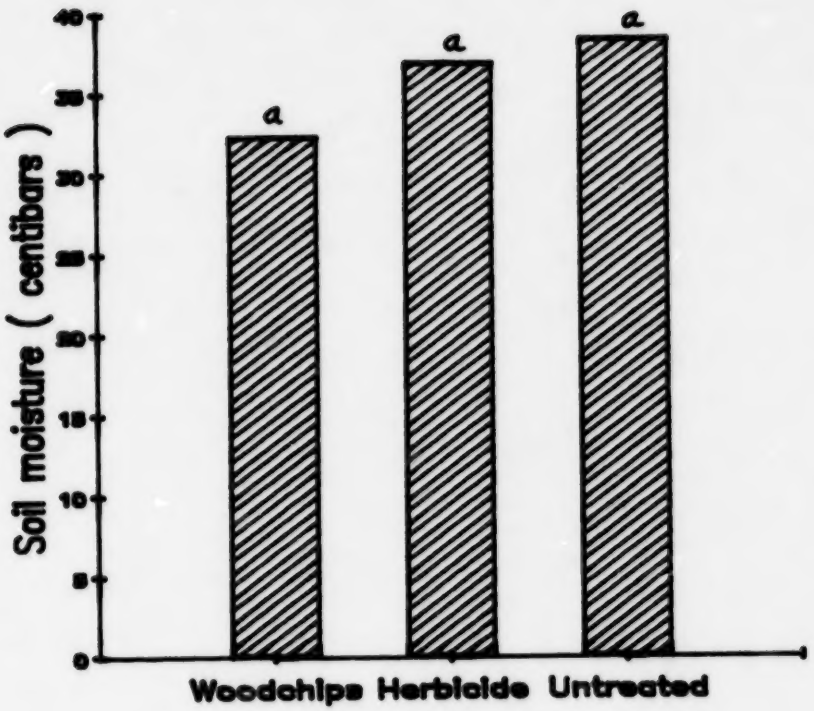


Fig. 13. Soil moisture in 1988 as influenced by mulch treatments. Zero centibars denotes saturated conditions. Bars with similar letters are not significantly different (P = 5%, LSD).

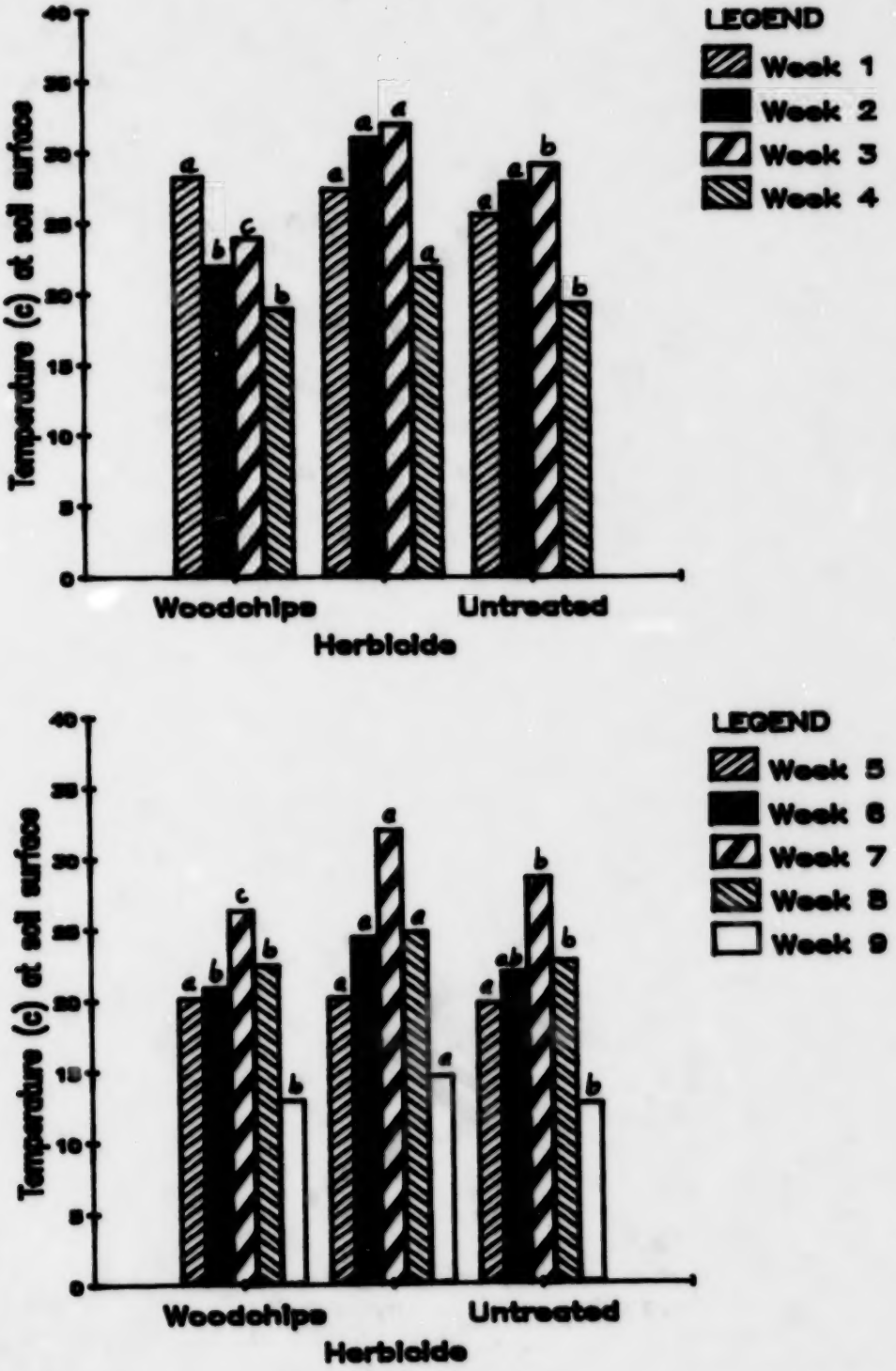


Fig. 14. Temperature at the surface for nine consecutive weeks in 1988 as influenced by surface treatment. Bars with similar letters, within weeks, are not significantly different (P = 5%, LSD).

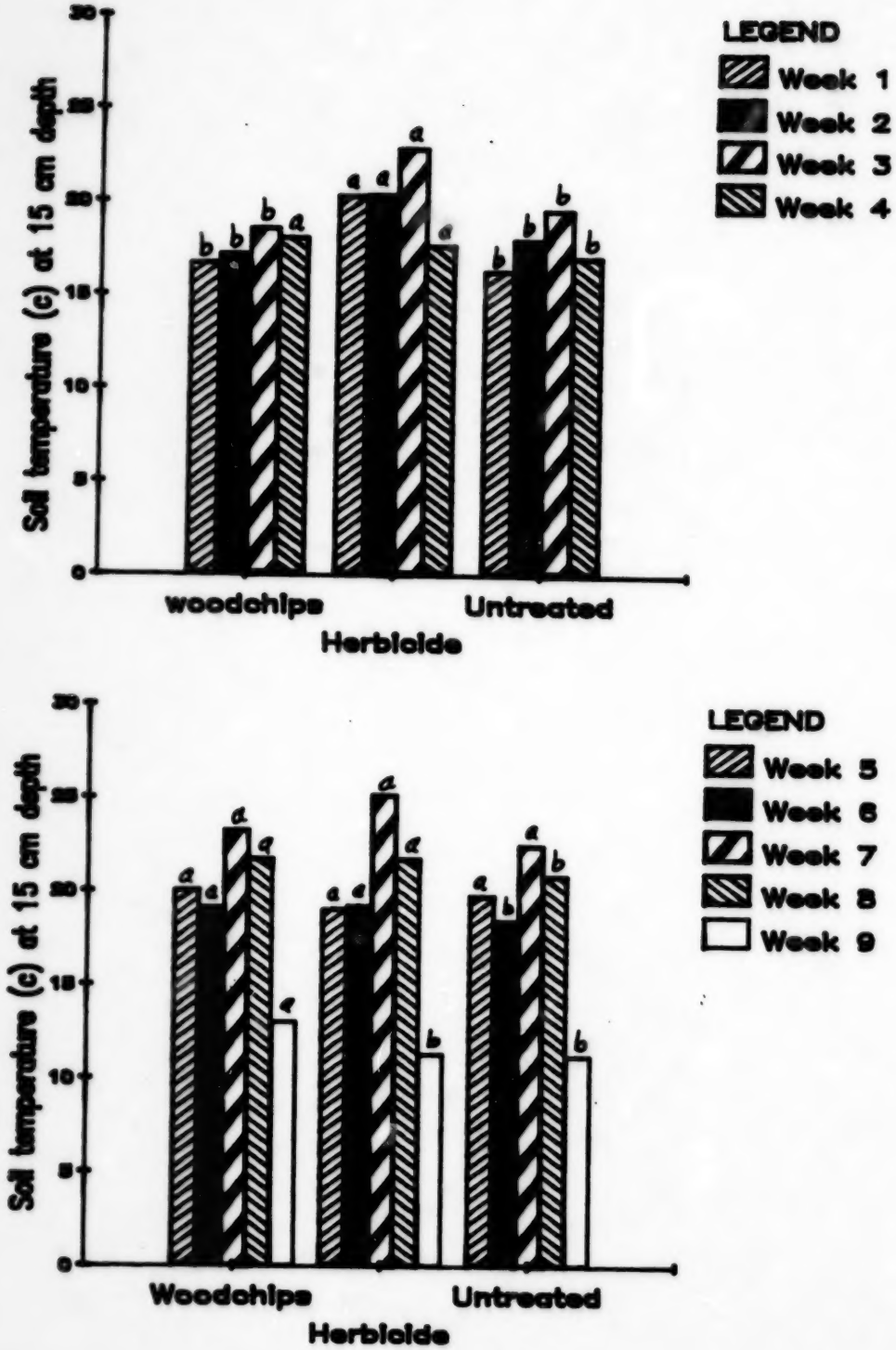


Fig. 15. Soil temperature, 15 cm deep, for nine consecutive weeks in 1988 as influenced by surface treatments. Bars with similar letters are not significantly different (P = 5%, LSD).

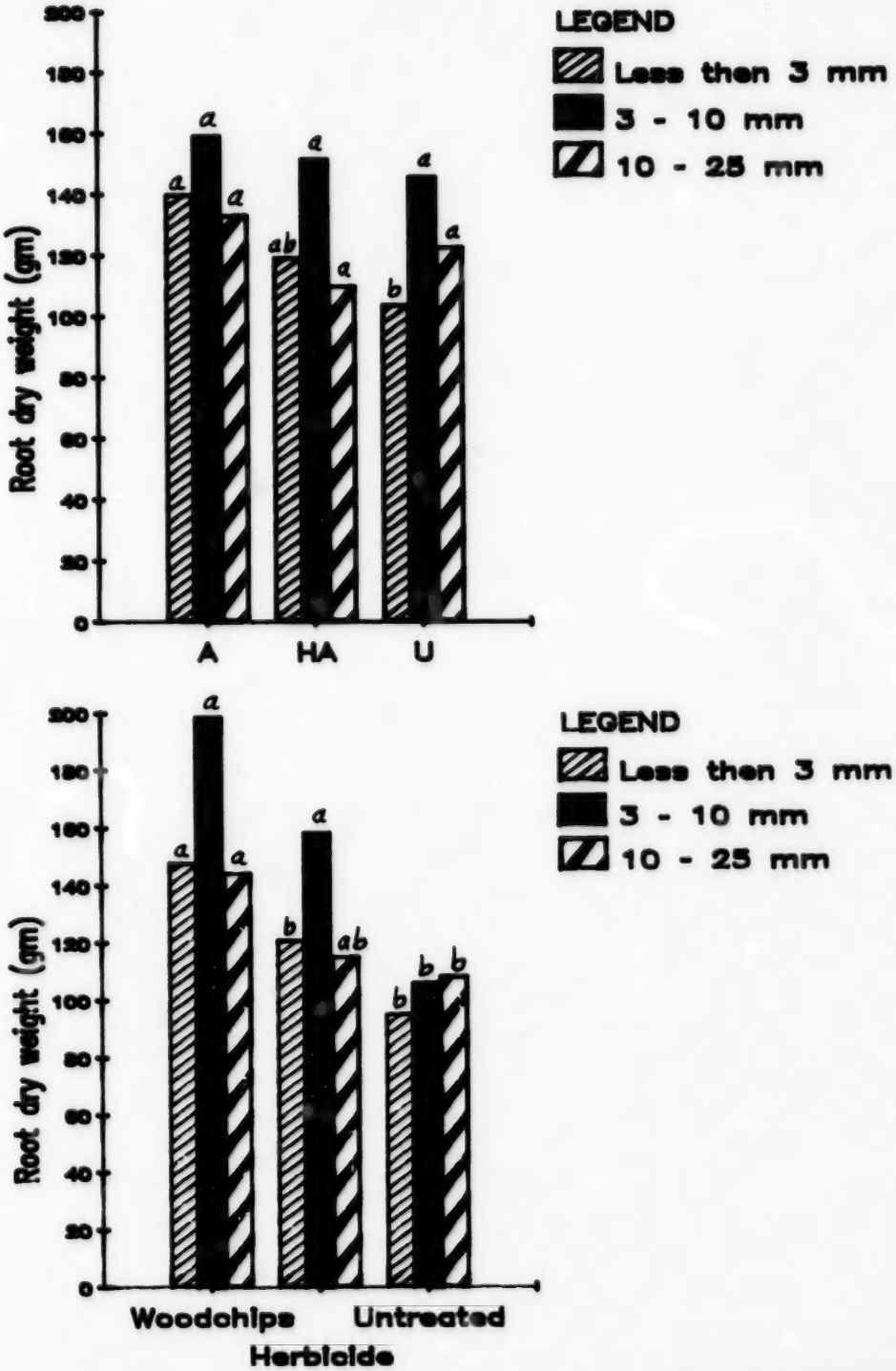


Fig. 16. Dry weight of three root size classes in 1988 as influenced by soil amendments (above) and surface treatments (below). Bars with similar letters are not significantly different (P = 5%, LSD).

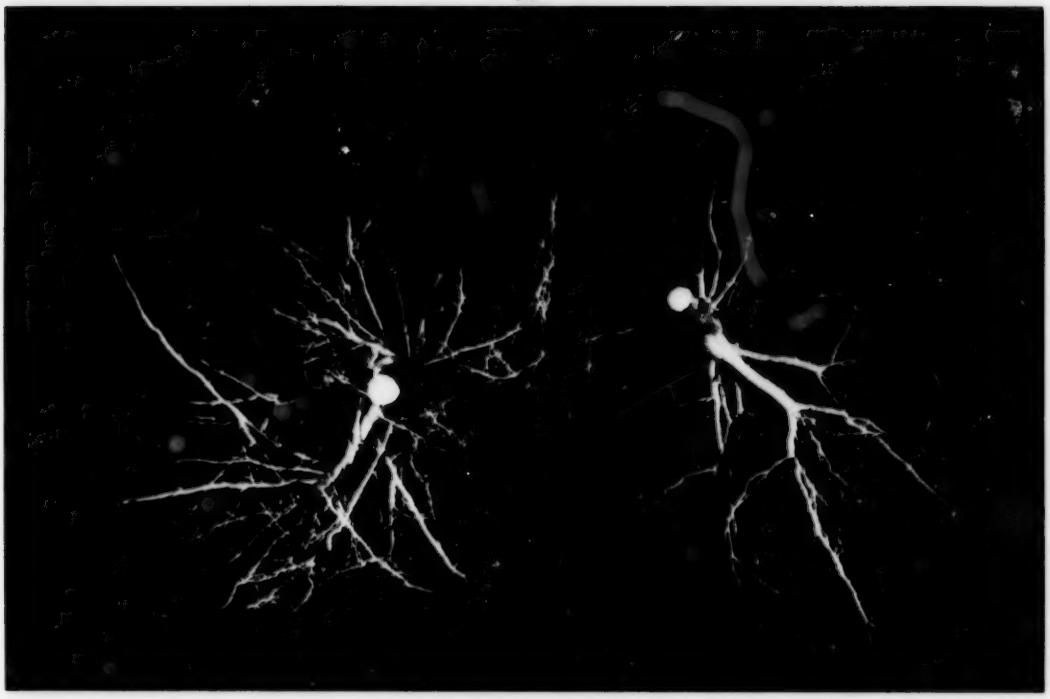


Fig. 17. More dense roots from amended backfill (left) as compared to those in unamended soil (right).

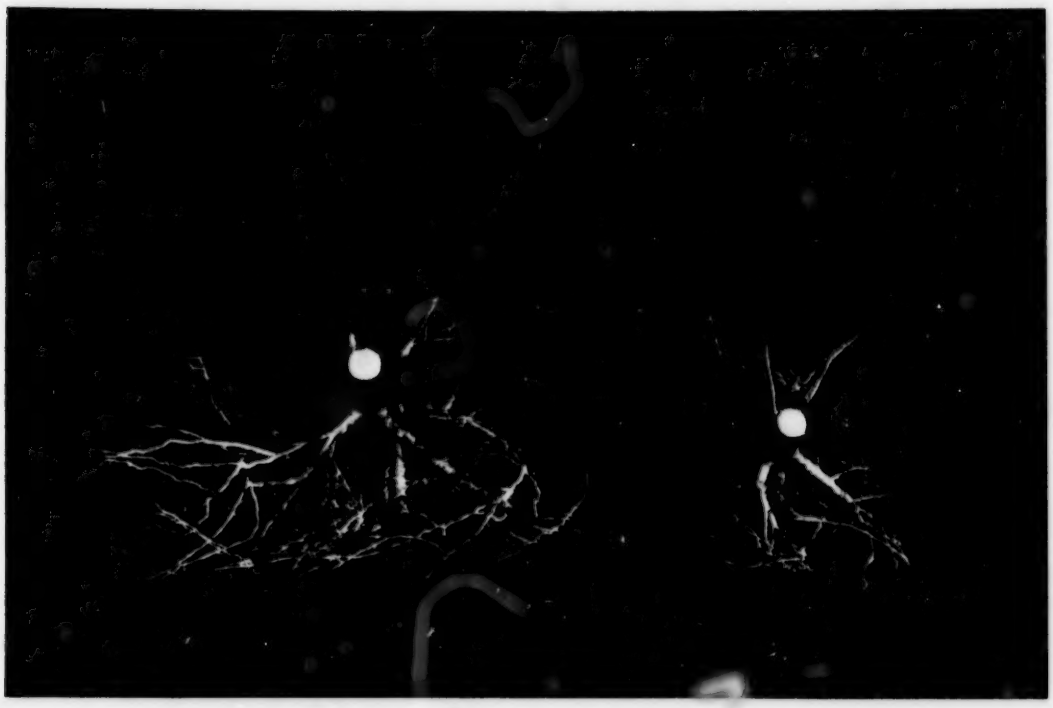


Fig. 18. More dense, fibrous roots under woodchip mulch (left) as compared to unmulched trees (right).

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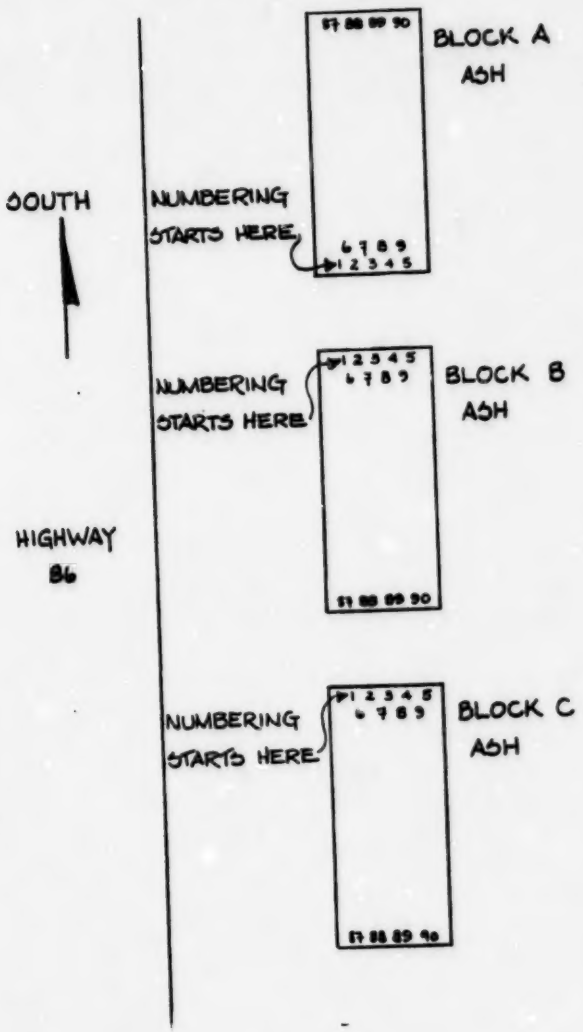


GENERAL NOTES

- TREES PLANTED MAY '85
- DESIGNATED TREES STAKED MAY '85
- BLOCK A MOST SOUTHERNLY NUMBERING STARTS AT NORTH END
- BLOCKS B AND C NUMBERING STARTS AT SOUTH END

MAINTENANCE:
H86 - HERBICIDE APPLIED '86
SRB6 - STAKE REMOVAL '86

SOIL AMENDMENTS:
A = AMENDED
NA = NOT AMENDED
HA = ½ AMENDED SOIL PLUS ½ NOT AMENDED

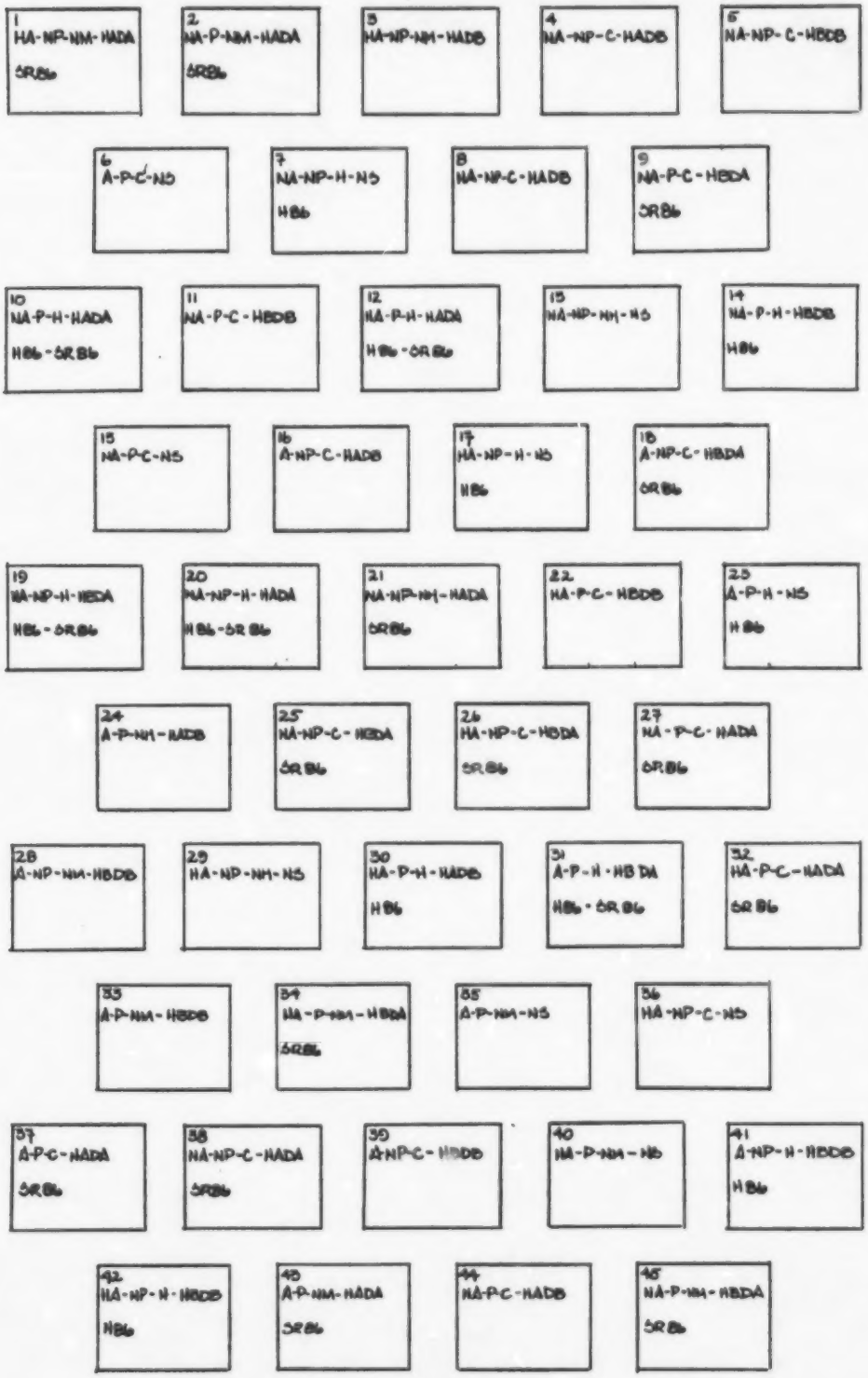
PRUNING:
P = PRUNED
NP = NOT PRUNED

MULCHING:
C = WOOD CHIPS
H = HERBICIDE
NM = NO MULCH

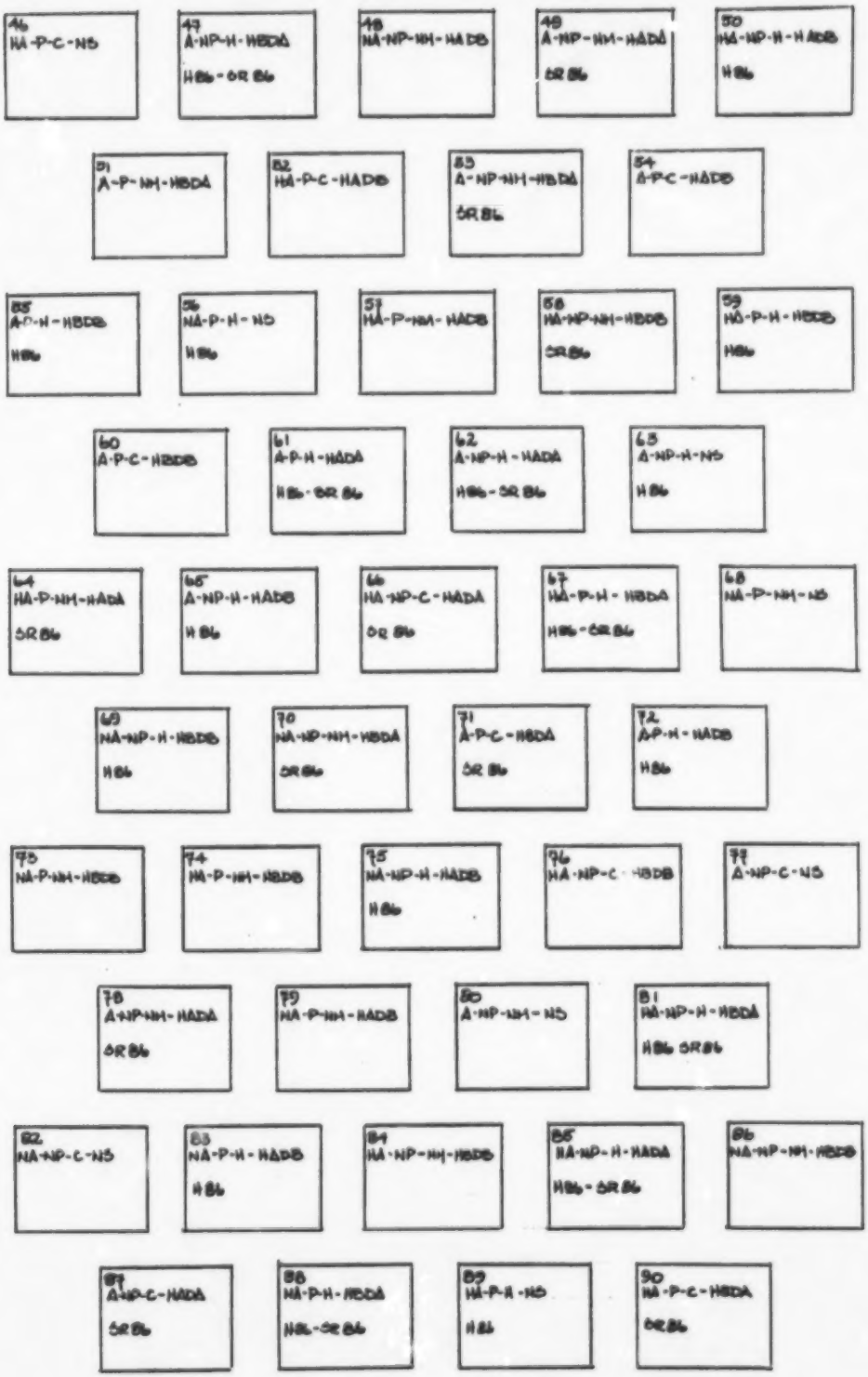
STAKING:
NS = NONE
HADA = HT. A (TALL), 1 YEAR
HADB = HT. A (TALL), 3 YEARS
HBDA = HT. B (SHORT), 1 YEAR
HBDB = HT. B (SHORT), 3 YEARS

ASH - BLOCK A

SOUTH BLOCK, NUMBERING STARTS AT NORTH END



ASH- BLOCK A


46
HA-P-C-NS
47
A-NP-H-HBDA
HB6-SR B6
48
HA-NP-HH-HADB
49
A-NP-HH-HADA
SR B6
50
HA-NP-H-HADB
HB6
51
A-P-HH-HBDA
52
HA-P-C-HADB
53
A-NP-HH-HBDA
SR B6
54
A-P-C-HADB
55
A-P-H-HBDB
HB6
56
HA-P-H-NS
HB6
57
HA-P-HH-HADB
58
HA-NP-HH-HBDB
SR B6
59
HA-P-H-HBDB
HB6
60
A-P-C-HBDB
61
A-P-H-HADA
HB6-SR B6
62
A-NP-H-HADA
HB6-SR B6
63
A-NP-H-NS
HB6
64
HA-P-HH-HADA
SR B6
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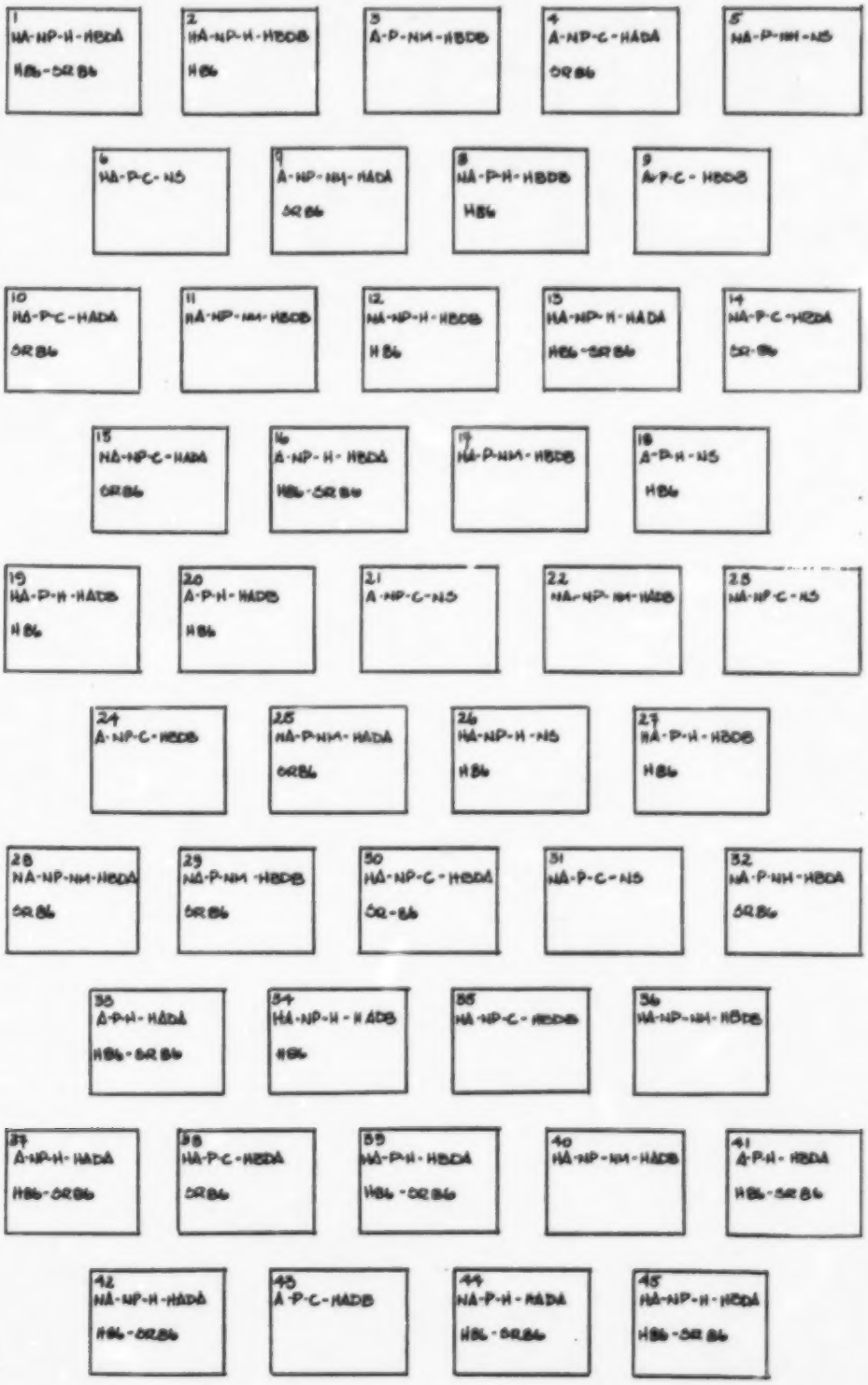
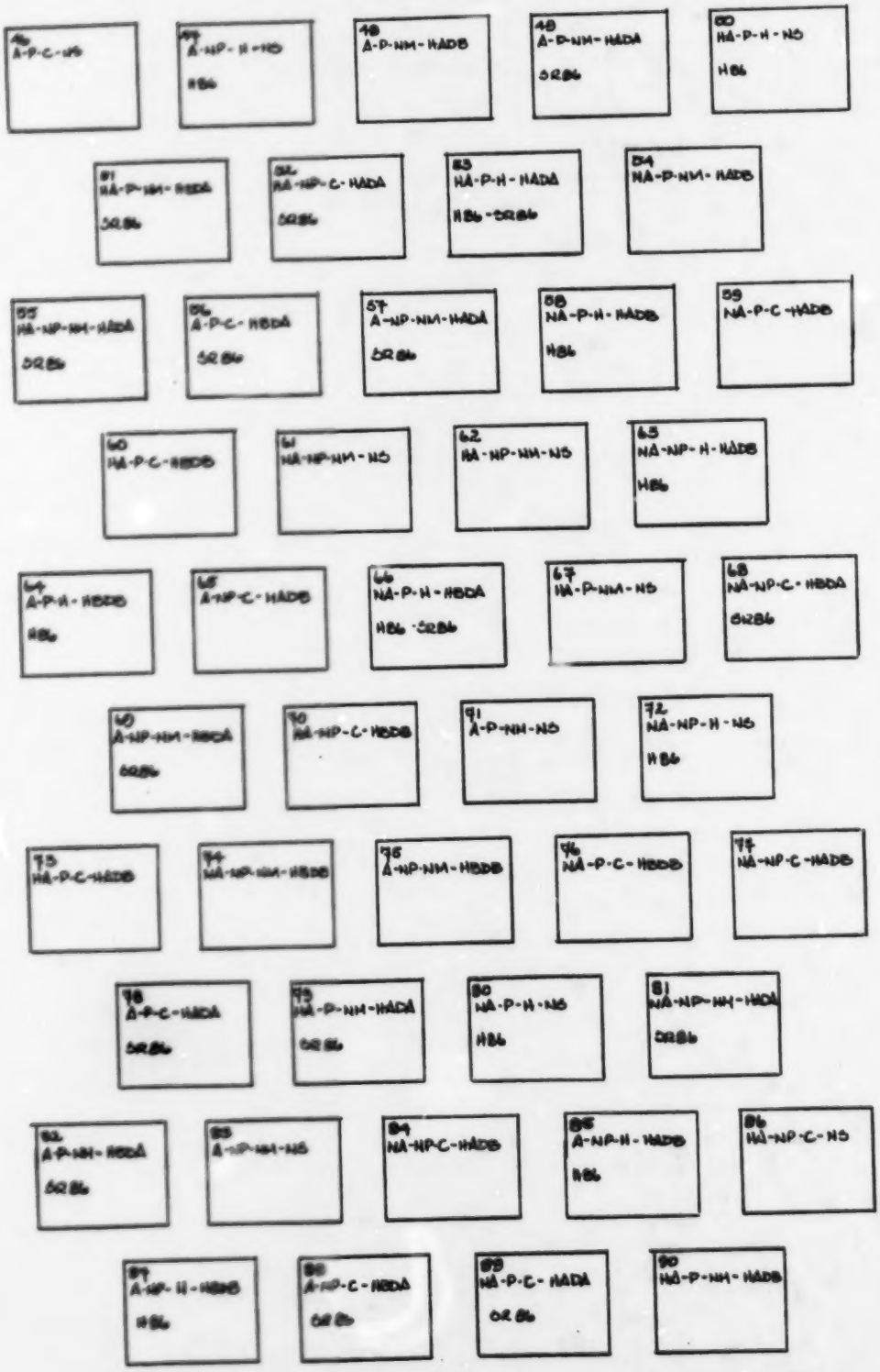
A-NP-H-HADB
HB6
66
HA-NP-C-HADA
SR B6
67
HA-P-H-HBDA
HB6-SR B6
68
HA-P-HH-NS
69
HA-NP-H-HBDB
HB6
70
HA-NP-HH-HBDA
SR B6
71
A-P-C-HBDA
SR B6
72
AP-H-HADB
HB6
73
HA-P-HH-HBDB
74
HA-P-HH-HBDB
75
HA-NP-H-HADB
HB6
76
HA-NP-C-HBDB
77
A-NP-C-NS
78
A-NP-HH-HADA
SR B6
79
HA-P-HH-HADB
80
A-NP-HH-NS
81
HA-NP-H-HBDA
HB6 SR B6
82
HA-NP-C-NS
83
HA-P-H-HADB
HB6
84
HA-NP-HH-HBDB
85
HA-NP-H-HADA
HB6-SR B6
86
HA-NP-HH-HBDB
87
A-NP-C-HADA
SR B6
88
HA-P-H-HBDA
HB6-SR B6
89
HA-P-H-NS
HB6
90
HA-P-C-HBDA
SR B6

ASH- BLOCK B

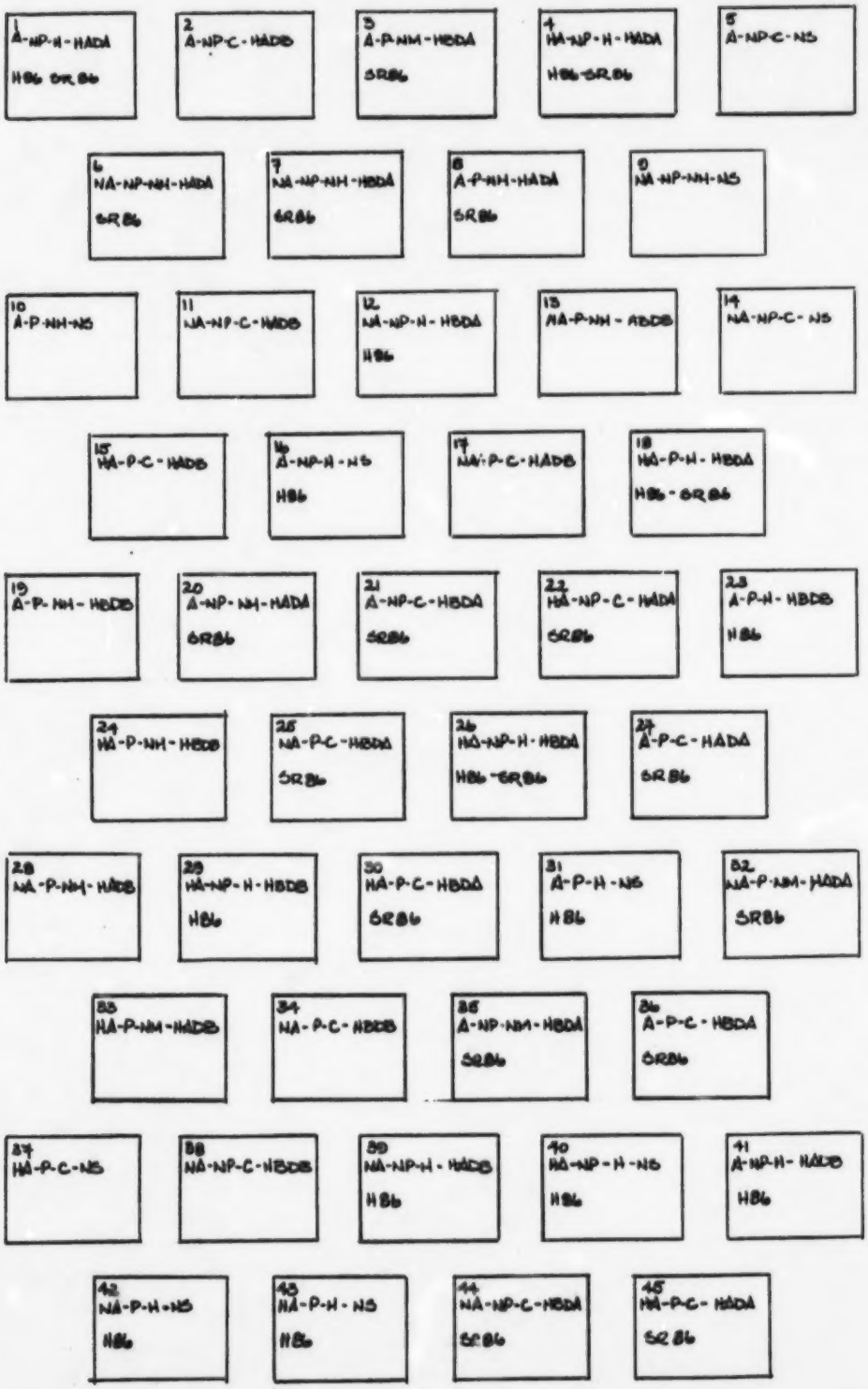
NUMBERING STARTS AT SOUTH END



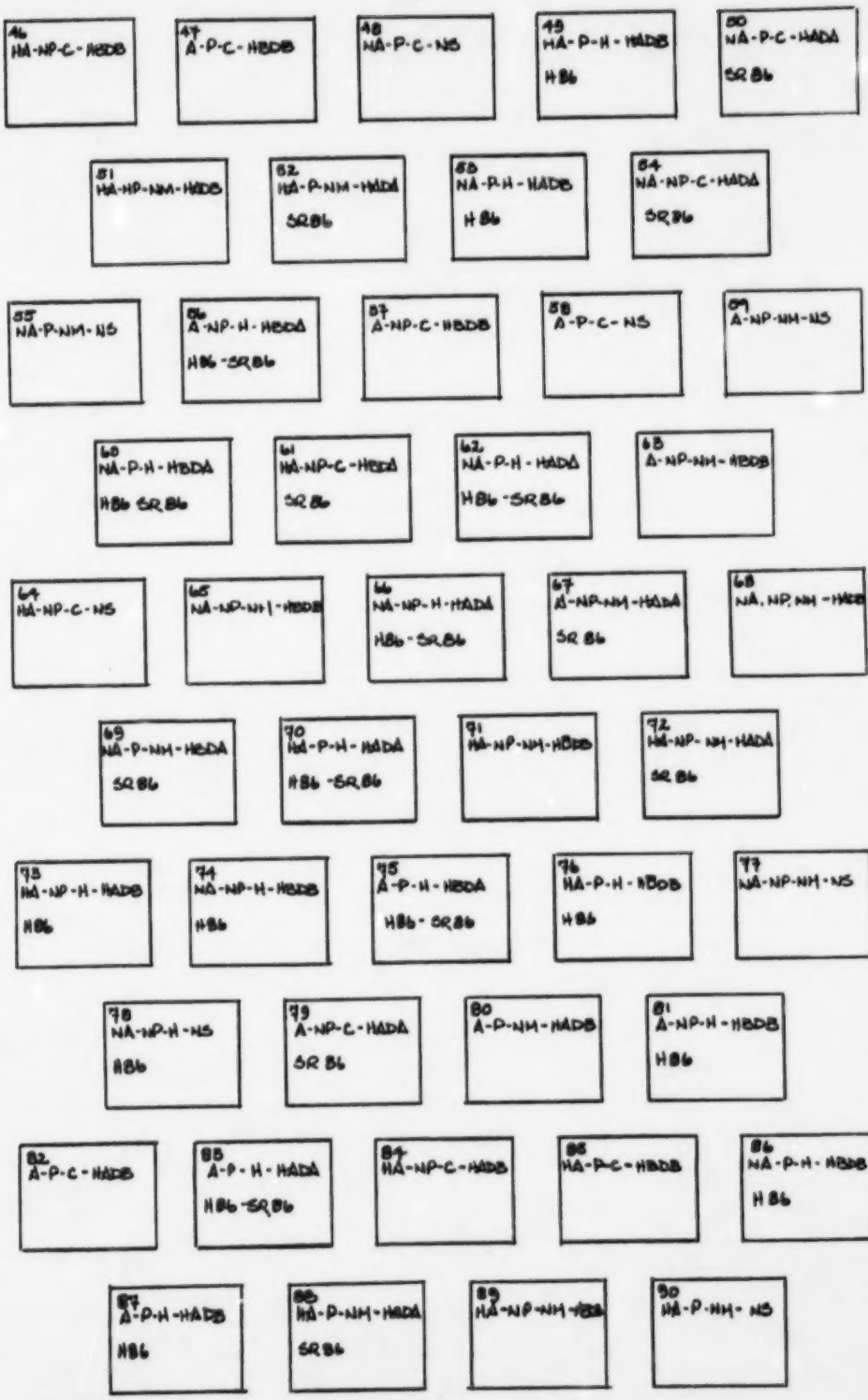
ASH - BLOCK B


45 A-P-C-NS
46 A-NP-H-NS HB4
47 A-P-NM-HADB
48 A-P-NM-HADA SR84
49 HA-P-H-NS HB4
50 HA-P-NM-HBDA SR84
51 HA-NP-C-HADA SR84
52 HA-P-H-HADA HB4-SR84
53 HA-P-NM-HADB
54 HA-NP-NM-HADA SR84
55 A-P-C-HBDA SR84
56 A-NP-NM-HADA SR84
57 HA-P-H-HADB HB4
58 HA-P-C-HADB
59 HA-NP-NM-NS
60 HA-P-C-HBDB
61 A-P-H-HBDB HB4
62 A-NP-C-HADB
63 HA-P-NM-NS
64 HA-NP-H-NS HB4
65 HA-NP-C-HBDA SR84
66 A-NP-NM-HBDA SR84
67 A-P-NH-NS
68 HA-P-C-HADB
69 A-P-H-HBDB HB4
70 HA-NP-C-HBDB
71 A-P-NH-NS
72 HA-NP-H-NS HB4
73 HA-P-C-HADB
74 HA-NP-NM-HBDB
75 A-NP-NM-HBDB
76 HA-P-C-HBDB
77 HA-NP-C-HADB
78 A-P-C-HADA SR84
79 HA-P-NM-HADA SR84
80 HA-P-H-NS HB4
81 HA-NP-NM-HADA SR84
82 A-P-NM-HBDA SR84
83 A-NP-NM-NS
84 HA-NP-C-HADB
85 A-NP-H-HADB HB4
86 HA-NP-C-NS
87 A-NP-H-HBDB HB4
88 A-NP-C-HBDA SR84
89 HA-P-C-HADA SR84
90 HA-P-NM-HADB

ASH-BLOCK C
NUMBERING STARTS AT SOUTH END



ASH-BLOCK C


46
HA-NP-C-HBDB
47
A-P-C-HBDB
48
HA-P-C-NS
49
HA-P-H-HADB
HB6
50
HA-P-C-HADA
SR B6
51
HA-NP-NM-HBDB
52
HA-P-NM-HADA
SRB6
53
HA-P-H-HADB
HB6
54
HA-NP-C-HADA
SR B6
55
HA-P-NM-NS
56
A-NP-H-HBDA
HB6-SRB6
57
A-NP-C-HBDB
58
A-P-C-NS
59
A-NP-NM-NS
60
HA-P-H-HBDA
HB6 SR B6
61
HA-NP-C-HBDA
SR B6
62
HA-P-H-HADA
HB6-SRB6
63
A-NP-NM-HBDB
64
HA-NP-C-NS
65
HA-NP-NM-HBDB
66
HA-NP-H-HADA
HB6-SRB6
67
A-NP-NM-HADA
SR B6
68
HA-NP-NM-HBDB
69
HA-P-NM-HBDA
SR B6
70
HA-P-H-HADA
HB6-SRB6
71
HA-NP-NM-HBDB
72
HA-NP-NM-HADA
SR B6
73
HA-NP-H-HADB
HB6
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HA-NP-H-HBDB
HB6
75
A-P-H-HBDA
HB6-SRB6
76
HA-P-H-HBDB
HB6
77
HA-NP-NM-NS
78
HA-NP-H-NS
HB6
79
A-NP-C-HADA
SR B6
80
A-P-NM-HADB
81
A-NP-H-HBDB
HB6
82
A-P-C-HADB
83
A-P-H-HADA
HB6-SRB6
84
HA-NP-C-HADB
85
HA-P-C-HBDB
86
HA-P-H-HBDB
HB6
87
A-P-H-HADB
HB6
88
HA-P-NM-HADA
SRB6
89
HA-NP-NM-HBDB
90
HA-P-NM-NS